# Just in Time: Teaching Electromagnetics in the 21st Century

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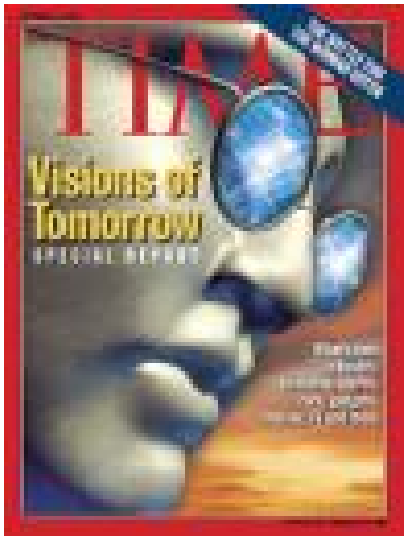
Once upon a time, a standard four-year undergraduate curriculum in electrical engineering (EE) in the US required a full year devoted to electromagnetics (EM), with often a semester devoted to static fields and another to electromagnetic waves, transmission lines, radiation, etc. However, as new engineering topics related to electronic/photonic/digital/computer- technologies have seeped into the modern EE curriculum (which remains stuck at four years), university faculty members (and their industrial advisory boards) have often engaged in spirited debates on which subjects constitute *core* knowledge. As a consequence, current EE curricula are all over the map, ranging from a *required* full-year of EM to an *optional* one-semester course. It is not that people do not realize the important role of EM in their lives (from microwave ovens to cellular wireless networks), there simply are too many important engineering subjects that are deemed just as worthy of inclusion in the modern EE curriculum.

I would like to propose a *restructuring* of the first (often the *only*) course in engineering electromagnetics so that it will excite the imaginations of not only electrical engineers but also other science/engineering students (with standard calculus and physics as prerequisites). The course will not be encyclopedic but will still draw material from both static and dynamic fields. Furthermore, each lecture will start with a question related to everyday life (e.g., are cell phones safe to use?), then proceed with an investigation of the issue, initially non-mathematically (the "short answer") and then lead to a more detailed theoretical exposition (the "long answer"). Students will learn how to *formulate* good engineering problems. Mathematical concepts will be introduced as needed ("just in time") and the treatment will *not* be general but rather as simple as possible in the context of the problem. Additional mathematical material may be covered in homework assignments or small projects. Such an approach to teaching network theory has been tried successfully by Mung Tiang at Princeton University and is presented in his recent book **Networked Life: 20 Questions and Answers** (Cambridge University Press, 2012).

It may be noted in passing that the current ABET accreditation criteria for electrical engineering programs emphasize that students, in addition to mastering the technical content, become conversant with the *societal* and *ethical* implications of technologies and learn to place the engineering subject matter in the broader *global* context. The restructured EM course also goes some distance in filling that niche in a student's technical education. Another goal is to entice the reader into pursuing the sources for a lecture topic to delve more deeply into the subject ["*life-long learning*"].



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# Outline

- Current approaches to EM education
- Proposed approach: inspiration
- Proposed approach: overview
- Proposed approach: one example
- Conclusions

# Current approaches to EM Education-I

Role in the EE Curriculum:

- Required: 1 year-long EM course(s)
- Required: 1 semester-long EM course
- Optional: 1 semester-long EM course

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# Current approaches to EM Education-II

EM Course Content:

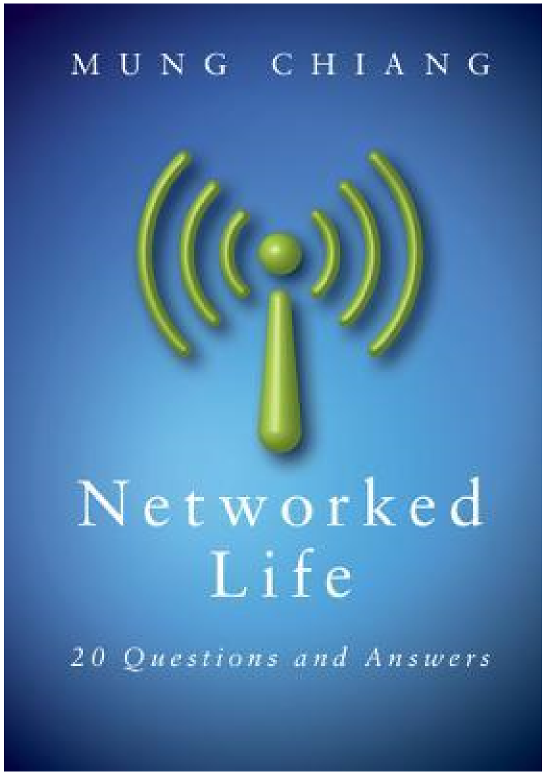
- Traditional: vectors, statics, TLs and waves
- Variation 1: TLs, vectors, statics, waves
- Variation 2: vectors, MEs, waves, statics

# Current approaches to EM Education-III

EM Course design:

- Modeling and visualization tools (e.g., MATLAB)
- Virtual laboratory experiments
- Active learning exercises
- Assessment tools (e.g., concept inventories)
- Web-based instruction

# Proposed approach: inspiration-I

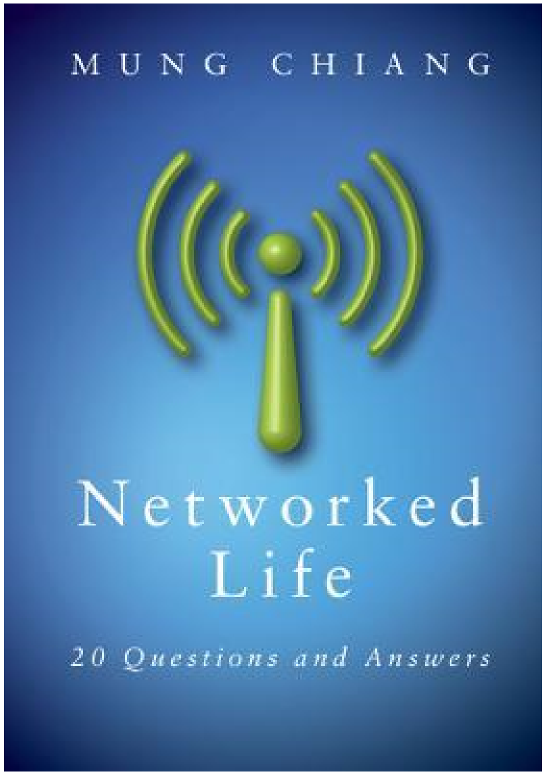


**Premise:** The majority of students will *not* pursue a career specializing in EM.

**Therefore**, the course should be viewed as:

- an appetizer, not a main course.
- a slide show not an encyclopedia.
- free of material that may interest EM researchers but is *not* essential.

# Proposed approach: inspiration-II

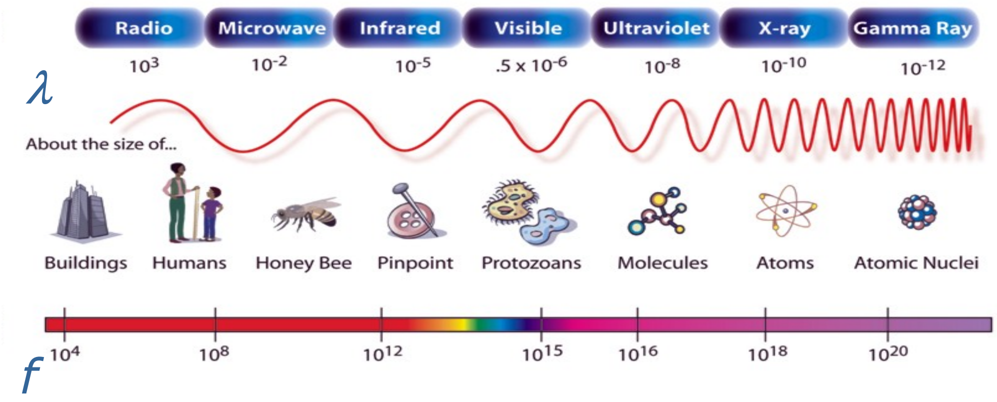


Chiang designed his **Networks** course around questions a student can relate to:

- ➢How does Netflix recommend movies?
- ➢Why does Wikipedia even work?
- ➢Why is WiFi faster at home than at a hotspot?

# Proposed approach: overview

✓Start each module with a question that is relevant to modern life
✓Discuss a non-mathematical "short answer"
✓Develop a "long answer" with just-enough mathematics introduced as needed ("just in time")
✓Make the treatment *not* general but as simple as possible in the context
✓Place the answer in the broader societal context
✓Encourage students to delve more deeply into *some* of the topics



# Proposed approach: example -I

- *So let us try to pick a question.*

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**"Hello, Bob? It's your father again.
I have another question about my new computer.
Can I tape a movie from cable TV then fax it from
my VCR to my CD-ROM then E-mail it to my
brother's cellular phone so he can make a
copy on his neighbor's camcorder?"**

# Proposed approach: example –II

**Question:** Can my iPhone cause cancer?

# Proposed approach: example –III

**Question:** Can my iPhone cause cancer?

**"Short" Answer:** No*, because ..

✓Microwave photons are *non-ionizing*

✓Low-intensity RF >little heating

✓ FDA: The weight of scientific evidence has not linked cell phones with any health problems.

# Proposed approach: example –IV

**Question:** Can my iPhone cause cancer?

**"Long" Answer:** Let us look at it in detail

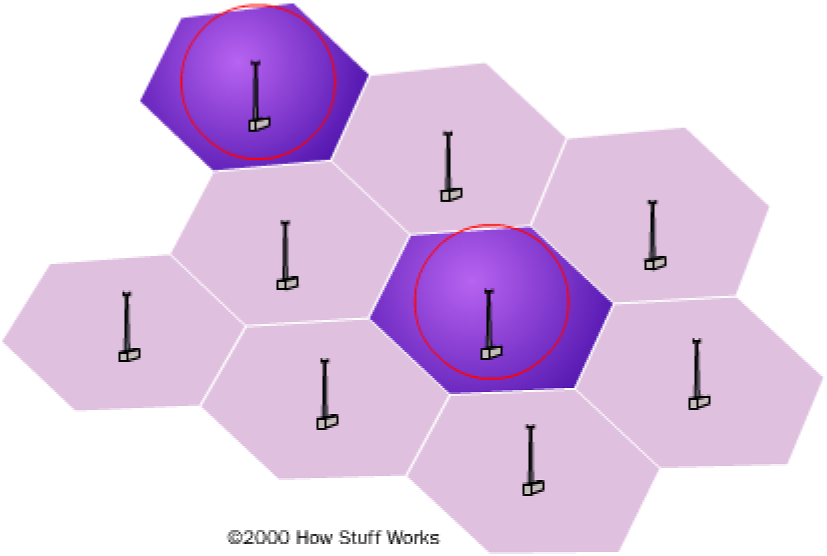
✓How does the cell phone system work?

✓What is in my iPhone?

✓ How are microwaves reflected and absorbed by the human body?

# Proposed approach: example –V : The cell phone system

- In a cellular phone network, each geographical region is divided into a number of hexagonal area called ***cells***
- Each ***cell*** is centered around a base station that receives and transmits RF signals to and from the cell phones in the cell.



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# Proposed approach: example –VI : Inside an iPhone

- Cell phones include the following parts:
  - Antenna
  - Display
  - Speaker
  - RF Circuits
  - Microphone
  - …

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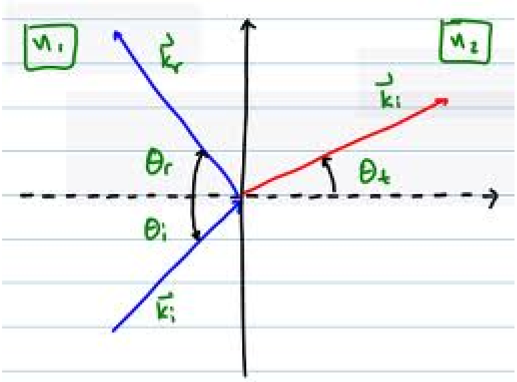
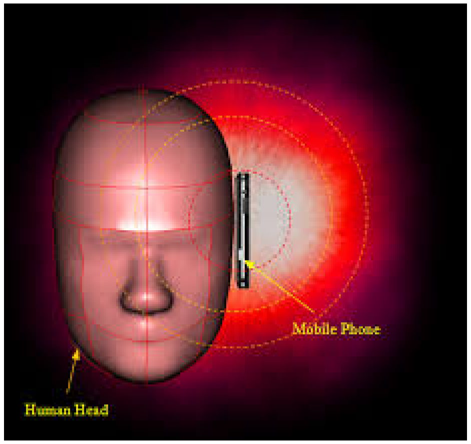
# Proposed approach: example –VII : RF Absorption

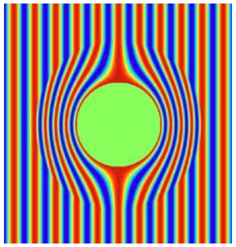
When EM waves encounter objects, they may be reflected and or absorbed.



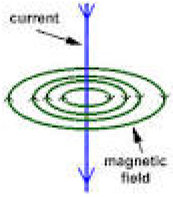


# Proposed approach: example –VIII

## Some Other Questions:



- ➢Can I “cloak” my car against the police radar?



- ➢Is it safe to use an electric blanket/heating pad?

- ➢Can aliens watch our TV shows?

- ➢How smart is  a “smart grid”?
- ➢How do we get rid of all the battery charging cables?

# Conclusions

- The first EM course: Appetizer
- Framed around questions that matter
- Learning Objectives:
  - How EM technologies work
  - Terminology
  - Key concepts and equations
  - Impact on Society
  - The Past and the Future